VULNERABILITY ANALYSIS OF TRADITIONAL HOUSING IN DOMINICA

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Introduction

Dominica is situated in a region of the Caribbean that is subject to both hurricanes and earthquakes. The widespread damage caused by Hurricane David has underscored the vulnerability of the population and has shown that the housing stock of the vast majority of the people cannot withstand hurricanes. More than 70% of the people of Dominica live in non-engineered structures. Even within the larger cities (such as Roseau, Grand Bay and Portsmouth), architectural and engineering input into housing construction is minimal.

The purpose of this paper is to identify the most common housing types of non-engineered structures, to identify the structural problems of each type, and to determine their relative vulnerability to both high winds and earthquakes, together with identification of some options for improving the structural performance of each building type.

Basic Building Types

The two basic building materials used for housing in Dominica are wood and concrete block. Wood frame houses are most common, although the number of houses built with concrete block is increasing. There are many housing styles found throughout the country, and no one style is found exclusively in any single region. Generally speaking, wood frame construction represents the housing used by the lowest-income groups, while block is the material favored by those with more income (although it is not completely out of reach for low-income families).

The roofing material most often used is corrugated iron sheeting (known locally as "galvanized"). Some block houses use reinforced concrete slab roofs. Grass or palm leaf roofs are still found in the rural areas, although this type of roofing is rapidly being replaced by corrugated iron sheets. Corrugated asbestos cement sheets are also used, but generally only in the urban areas of the country.

The housing styles that have evolved in Dominica are not indigenous to the island, as the native Indian group (Carib) has been killed off or assimilated over the last 500 years. Thus, the housing types tend to be a mixture of

imitations of European designs.

Wood frame housing is fairly cheap, due to the extensive forests on the island. Concrete blocks must be made from imported cement and thus the cost of wooden housing is relatively lower, although transportation of the wood and price fluctuations still must be taken into consideration.

The majority of housing in low-income communities is built under the supervision of a construction tradesman. In the case of wooden houses, this tradesman will be a carpenter; in the case of block houses, he will be a mason. Typically, the prospective owner will contract with a tradesman to build a house. This person may or may not be a full-time builder, but usually he has had considerable previous experience and is someone in whom the homeowner-to-be has sufficient trust. Once the contract has been made, construction labor may be provided in one of two ways. First, the tradesman may simply contract with other tradesmen who have less training, to assist in the construction. This is usually the case in the construction of a block house. The other, more widespread method is through participation of family members, with the father and one or more of the sons helping out. This is especially the case in the construction of wooden houses.

Only within urban areas are significant numbers of houses built entirely by the homeowner and his family. Yet even in these areas, the tradition of using the tradesman is still prevalent.

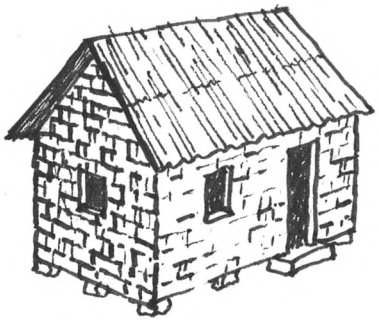
This normal process of building, through the use of tradesmen, must be taken into consideration by any development or relief agency seeking to initiate a housing program. Any such program must concentrate on teaching the tradesmen how to build a better house -- not the public at large. While certain general promotional activities are necessary in order to create an atmosphere of acceptance for any proposed changes, programs that encourage self-help construction by families without the participation of a tradesman will generally find the effort wasted.

Vulnerability Analysis of Traditional Housing

The following is an analysis of the principal housing styles found in Dominica, presented in ascending order of both cost and design sophistication. The primary emphasis of the analysis will be to explore the wind resistant potential of each structure, as hurricanes and wind storms are the greater risk

due to their greater frequency and return interval. However, the earthquake resistant potential will also be briefly identified.

1. Wood Frame House



The most common type of house among low-income families is a small wood-frame structure with a roof of galvanized corrugated iron sheets. These structures come in a variety of sizes, although the most common size is approximately 10-12 feet wide and 15-20 feet long. The houses are very lightweight and are made from lumber cut on the island.

Many of the houses have no foundation other than concrete blocks, rocks or concrete "feet" on which the house sits.

This type of house was rather severely damaged in the hurricane. Typical damage included the loss of the roof due to uplift on the eaves and lack of sufficient nails to fasten the galvanized sheets to the roof frame, and damage caused by the wind lifting the structure off the ground and pushing it into another object, or in some cases actually rolling the building.

The weak points of this type of structure include the connection between the roof frame and the walls, and the lack of proper anchoring of the structure to the ground.

The following actions will improve the structural performance of this type of building in high winds:

A. Changing the roof configuration from a gable to a hip roof.

B. Using a truss to support the roof, and anchoring the truss securely to the walls by means of metal straps.

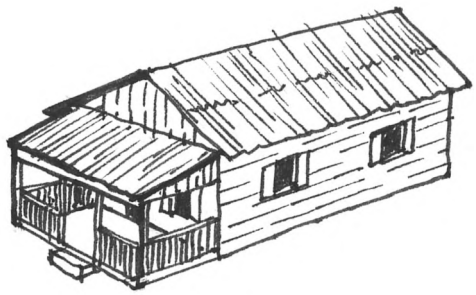
C. Anchoring the house to the ground through the use of corner posts which are sunk into the ground and placing a rock or concrete block foundation around the structure at the base, so that the wind cannot

come up under the house.

If the above recommendations are followed, the structural performance of the building will be improved by approximately 25%, and the building should offer moderate to good protection during high winds.

This type of structure is very safe, as is, in earthquakes. Wood frame buildings are lightweight and, with the lightweight roof used in Dominica, the structure should suffer only minimal damage during an earthquake. The actions recommended above for improving the structural performance in high winds will further improve the earthquake resistance of this type of building.

2. Wood Frame Housing, Urban Style



This type of structure is found throughout most of the urban areas of Dominica, and a few variations are found in the rural areas. This house uses prepared lumber nailed to a wooden frame which is anchored to the ground by extending the vertical columns of the frame into the ground approximately 12"-18". The majority of these houses use a gable roof configuration, and the roofing material is corrugated galvanized iron sheets.

Most of the homesites in the urban areas are narrow along the street front and longer as they extend to the rear of the lot. The entrances to most urban houses are in the narrow wall which faces the street. The house illustrated in the drawing above has a typical entryway made of wood with a porch covered by galvanized roofing.

This type of house suffered relatively little damage during Hurricane David. The most typical type of damage was the loss of the roofing material and damage to the porch. Otherwise, the structures tended to remain intact.

The weak points of the houses are the connection between the porch and the

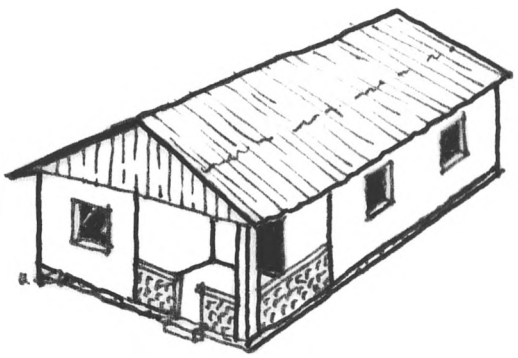
main structure of the building, the connection between the roof structure and the walls of the house, and the fastenings of the galvanized roofing materials to the roof frame.

The only recommended modification to improve structural performance during high winds is to reconfigure the roof from a gable roof to a hip roof configuration. Additionally, roofs should not extend more than 18" beyond the side of the wall, and the area beneath the overhang should be closed with an eave to reduce uplift on the edges of the roof. The posts that are in the ground should, of course, be treated to prevent deterioration.

If the above recommendations are carried out, the wind resistant potential should be fairly high.

Structures of this type have an excellent record of performance in earthquakes. No changes need to be made in the building in order to make it more earthquake resistant. The changes recommended above for wind resistance will not contribute substantially toward making the house more resistant to earthquakes, but the measures will help to some degree.

3. Single-story Concrete Block House



Concrete block houses are being constructed more and more each year. They are popular because they offer two advantages: durability and climatic comfort. The typical one-story block house is made using reinforced concrete columns and a concrete ring beam at the top of the block wall (although less than half have ring beams in the center of the wall). Roofs are normally covered with galvanized roofing material resting on a frame attached to a truss system.

During Hurricane David, almost all of the concrete block houses in the country lost their roofs. This is due to a weak connection between the truss system and the ring beam. Furthermore, most of the houses built in this manner have relatively flat roof pitches and fairly large overhangs.

The configuration shown in the drawing is very popular. Unfortunately, the porch provides an excellent place for the wind to come up under the roof and lift the roof off the building.

Other weak points of the house include louvered windows which allow excessive amounts of air to enter the structure, creating positive pressure inside the house which pushes outward on the walls and upward on the roof.

The following actions are recommended in order to improve the structural performance of this type of house in high winds:

A. Changing the roof configuration from a gable to a hip roof.

B. Developing a better connection between the roof truss and the upper ring beam of the house.

C. Shuttering all louvered windows.

D. Using a full porch instead of a quarter porch, and designing it in such a way that the porch can separate from the house in a wind storm without doing structural damage.

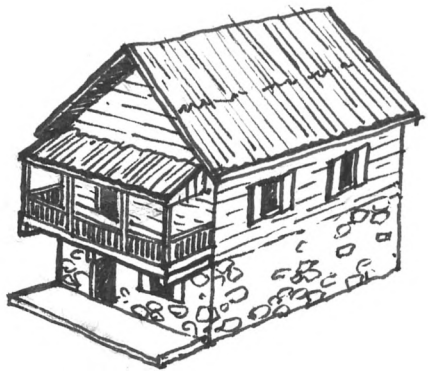
E. Placing sufficient columns and ring beams in the walls to provide additional strength against the gust effects of high winds. Columns should be a maximum of 2½ yards apart.

F. Keeping overhangs to a maximum of 18". Build an eave under the overhang to prevent excessive amounts of air from being trapped under the overhang and contributing to roof uplift.

If these recommendations are followed, the wind resistant potential of these houses will increase substantially and the typical damage, especially the loss of roofs, will be reduced significantly.

Block houses have a fairly good record of performance during earthquakes, as long as they are properly reinforced and have lightweight metal roofs. The reinforcement necessary for earthquakes is identical to that required for wind resistant construction. Therefore, any improvements made in a block house to make it more wind resistant will also serve to make it more earthquake resistant. Care should be taken to build a good strong foundation for a block house. This is more critical in terms of earthquakes than in terms of high winds, but it will serve to increase the endurance of the house, especially at the base of the structure.

4. Two-story Wood Frame House on Rock or Block First Story



In the urban areas of Dominica, there is an evolutionary process of building which is evident in many of the two-story structures. People first build a wooden frame house and live in it for a number of years. After they gather sufficient money and materials, the wooden house is taken down in sections and a new ground floor is built of rock or concrete block; the older house is reassembled as the upper floor of the new house. These structures are quite popular and can be seen throughout Roseau. A unique feature of this type of house is the cantilevered front porch which projects out over the sidewalk on the street side of the house.

The upper story is made in the same way as the wooden houses described earlier -- a wooden frame house covered with a galvanized metal roof. The lower story is made either of concrete block (which may or may not be reinforced) or rock, cemented together to make a wall (again, which may or may not be reinforced).

This type of structure surprisingly weathered Hurricane David fairly well. The most typical damage was loss of roofing material and displacement caused by high winds pushing against the wooden structure and separating it at the joint between the upper building and the rock or block lower building.

The following actions are recommended in order to improve the structural performance of this type of house:

A. Using adequate reinforcing in the lower story, to prevent collapse of the lower story and to help distribute both the weight of the structure and any forces which might act on the sides.

B. Improving the connection between the upper and lower stories. This can be done by building a reinforced concrete ring beam at the top of the lower wall and placing numerous anchors where the wood frame is

attached to the lower story, and by developing a column system that extends to the upper story to give additional support to the walls.

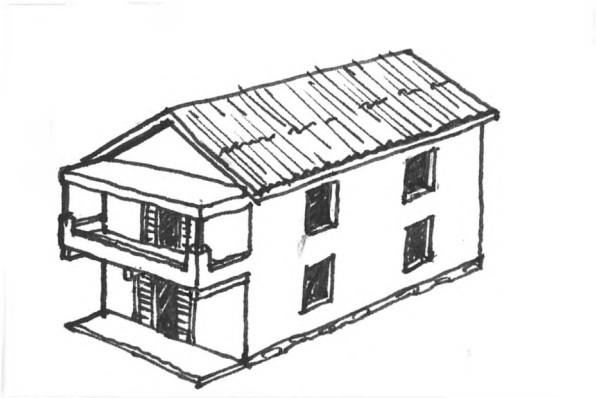
C. Using sufficient diagonal bracing at the corners to prevent distortion of the house during high wind loads on the upper portion of the building.

D. Following the recommendations made for wooden structures regarding the roof.

If these recommendations are followed, the wind resistant potential of the structure will continue to be fairly high although, because the structure is a two-story building, damage to the upper story will always be likely during a hurricane.

The earthquake resistance of a structure such as this is not particularly good. These structures are both high and narrow, and the high center of gravity makes it difficult to stabilize the house during the violent shaking caused by an earthquake. However, because the upper story is made of wood, the weight decreases as the building increases in height. If sufficient strength is added to the lower walls through adequate reinforcement using columns and ring beams, if the foundation is well made and the building anchored securely to the foundation, and if the wooden upper part of the building is securely fastened to the lower portion of the house, then this type of building could conceivably survive an earthquake of moderate magnitude.

5. Two-story Concrete Block House



The two-story concrete block house is a popular style found in the urban areas of Dominica. This structure also has the cantilevered front porch projecting out over the sidewalk and it is very similar in appearance to the type of structure described above. The primary advantage of this

house over the other is the continuous wall construction, as it offers the opportunity of reinforcing the entire wall with one continuous bond both vertically and horizontally.

This type of structure generally fared well during Hurricane David, suffering only minor damage caused by loss of the roofing material. Most of these houses are built with some form of engineering or architectural input into the design.

The only modifications to this type of structure which would increase the performance of the building, or its safety, would be the detailing of the roof and roof overhang. The cantilevered porch should, likewise, receive special attention to make sure that it does not break off in a wind storm or earthquake, sealing off the door.

The earthquake resistance of this type of structure should be fairly good, as long as adequate reinforcement is used throughout the building. In general, two-story structures in an earthquake-prone area are to be discouraged. But with the fairly infrequent return interval for earthquakes in this part of the Caribbean, specialized design considerations should be viewed in relation to their cost and how well they contribute to wind resistance rather than earthquake resistance.

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